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MODELLING OF TARGET ACQUISITION WITHIN COMBAT SIMULATION AND WARGAMES

Jan Vink

TNO-FEL

P.O. Box 96864

2509 JG The Hague The Netherlands

Tel: +31 70 3740126

Fax: +31 70 3740642

E-mail: J.K.Vink@fel.tno.nl

1. SUMMARY

This paper describes the target acquisition process from the perspective of modelling target acquisition as a part of modelling combat.

Exchanging fire obviously is very important in combat. Conditions for direct fire are line-of-sight (LOS) and some kind of perception of the intended target. LOS is deterministic and can be calculated if there is a good digital representation of the terrain. But perception is considered a stochastic process with probabilities depending on the current situation. In most stochastic combat simulation programmes and wargames there is a module that models detection and perception.

Because of the dynamic character of combat situations for observing are changing rapidly. The models are calculating situations every x seconds (typical 5 - 30). Within such a timeframe occurrences of events and the effects of these events are calculated. Illustrative events are new observations, firings, etc.

The target acquisition module is responsible for an actual list of observations. Each time-frame the list is updated: old observations are checked (observers or targets can be killed or moved) and new observations can be added. Because of the dynamic character only calculations are made for the coming time-frame. For each observer and each potential target an observation probability is calculated and comparison with a random number determines if the considered observer/target will lead to a new observation. Input for this module are elements of the situation at hand and characteristics of observer (such as the sensor used) and target (such as its dimensions).

This paper addresses some of the limitations and problems of the current implementation of the target acquisition module.

Keywords: combat simulation, wargame, detection modelling

2. INTRODUCTION

Simulating combat is a way of gaining quantitative insight in combat. Analysing historical data is another way of gaining insight, but this paper will not address that method.

Combat simulation models can be classified in different ways. One classification is the level of the military unit/system that can be simulated in the model. This can vary from the simulation of one system (eg. a sensor and its target) up to theatre level (the Gulf War). The examples used in this paper are at division and battalion level. These examples were chosen because both models have separate modules for

detection. In higher level models detection is a very abstract process (how can detection between two brigades be defined?).

This paper will shortly describe methods of combat simulation and then two examples will be described, first in general and then the detection module in more detail. The paper ends with some general requirements we have for a detection module.

In this paper detection is used as a general term. It can be defined as the level of perception needed for follow-on actions.

3. SIMULATING COMBAT

Combat is a very complex system and is impossible to predict. What can be done is gaining some quantitative insight which can support decision making. Simulation is a way of gaining this insight. Big advantage of simulation is the control over the conditions, the possibility to simulate non existing systems and unbiased interpretation of the outcome.

Simulating combat, why:

- (Weapon)system procurement
- Training & education
- Doctrine development
- Evaluating possible courses of action
- Force structure

Simulating combat, how:

- Field exercises
- Wargames
- Computerised combat simulation models
- Analytical models

The methods differ in detail of representation, the influence of the man in the loop (repeatability) and speed.

Computer models are used for wargames, combat simulation and analytical models. This paper will go into more detail in the detection modelling in some of the models we, at TNO-FEL, are working with. Please keep in mind that the detection module is only one of several modules the models are built upon.

4. EXAMPLES

4.1 The wargame Kibowi:

KIBOWI is a wargame, which is in use in the Dutch Army to support training & education of military staff. In a Kiowowi assisted exercise the military staff is out in the field, just like they would be in reality. They use their normal command & control equipment and procedures to prepare and give orders.

These orders go to the so-called lower-control. The lower control is organised in different cells (up to 50). Each cell has the control over a number of computer-represented units. The lower-control can give orders to these units and can get information about these units. This enables the lower-control to execute the orders from the staff. On the computer the lower-control has only access to the units under control.

Every timestep (typical 10 second) the computer evaluates all the orders and calculates line-of-sight, detections, firings, losses, stocks, etc.

If the computer determines there is detection, the detected units will pop-up on the relevant control-station. The lower-control concerned can report this detection to the staff, so they will be able to respond on the current situation. Another possibility for the lower-control is defining and sending a indirect fire-request to the cell that controls the artillery units.

Because of the performance-requirements of this wargame, complex calculations must be as limited as possible. There can be thousands of units and that can make millions of possible interactions. The terrain is represented as a 100*100m grid with a height and a terrain feature for each grid. Line-of-sight calculations are done separately and take a lot of time, so calculating detections cannot be too complex.

4.1.1 Detection calculation:

For every possible interaction two distances are calculated: a minimum- and a maximum distance (d_{min} and d_{max}). Detection probability is a function of these distances:

- If the distance d between the observer and the target is less or equal as d_{min} , then the detection probability = 1.
- If $d > d_{max}$ then the detection probability = 0
- Between the minimum and maximum distance the detection probability decreases linearly

The detection probability is compared with a drawing from a uniform distribution and this determines whether there is detection or not. The two distances depend on different factors:

- The default values for this observer-target combination (distances in an open area on a clear day)
- The status of the observer (moving, mounting, in assembly area, etc.)
- The status of the target (moving, in prepared position, etc.)
- The terrain feature around the target
- The weather
- The time of the day

Advantages of this method:

- Speed: all factors are in lookup-tables and almost no calculations are needed
- Simplicity: method is very easy to understand

Disadvantages of this method:

- Is the linear relation maybe oversimplified
- No interdependencies between factors
- No false alarms and no misperception

4.2 The combat simulation model FSM (Force Structure Model):

The most important characteristics of FSM are:

- Stochastic

- Closed (no man in the loop during simulation)
- Using 100*100m grid with height information and terrain feature on each grid
- Combination of timestep and event-driven. Typical timestep is 30 seconds.

One of the input-files is a scenario description. This file is written in a special designed language and contains orders and conditions for each unit. Every time-step orders and conditions are evaluated, for each unit new positions are calculated and new statuses are determined. After that the consequences of direct and indirect fire in that timeframe are calculated. For each shooter/target combination (called monel: one-sided duel) the next conditions are checked:

- is there line-of-sight between shooter and target
- is there a detection from shooter to target
- is the shooter allowed to fire
- is the target within the range of the weapon
- does the shooter has ammunition to shoot on this target

In case a shooter has more than one target, there are some decision-rules in the model to select which one to shoot at first. If a monel is selected an event is created. This event is scheduled according the time of arrival of the ammunition. The time of arrival is defined as the moment of detection + aiming-time + the flight-time. The list of events is evaluated in time-order and scheduled events can be deleted from the list in case of a firepower kill of a shooter before time of departure of its shot. After an event is handled a new event can be created. This can be a next shot against the same target or a shot against a new target. As long as the timeframe is not over, events are handled and created. If the timeframe is over, the computer starts with the next one.

The moment of detection is very important in this process. This means that the detection module not only calculates a probability of detection, it also determines a moment of detection. We use the following formula:

$$\text{Prob}(t_{\text{det}} \leq t) = 1 - e^{-t/T_{\text{mean}}}$$

T_{mean} is dependent from a lot of factors: distance, intrinsic contrast, weather, detection aids, statuses of observer and target, etc. With this formula the moment of detection is drawn randomly. If this moment is within the timeframe concerned then there is a detection. If the moment is not in the timeframe it will be ignored.

One of the reasons using this formula is that the length of the timeframe does not influence the probability function of the detection moment. A drawback is that the probability of detecting a target (p_r) ever goes to 1.

The way T_{mean} is calculated is based on a report of Night Vision Laboratories: "Simulating combat under degraded visibility". It calculates the number of resolvable cycles across the target and uses this to determine a probability of detecting the target within one glimpse. Next p_r and a mean time under the condition of detecting are derived. T_{mean} is calibrated with the last two variables.

Known shortfalls in the current implementation:

- The only memory implemented is that detections are not lost if LOS is not interrupted. If LOS is interrupted the detection will be forgotten
- The intrinsic contrast does not depend on the position in the field

- A group of vehicles is regarded as a group of independent targets
- There are no false alarms
- The number of resolvable cycles required for 50% detection is constant in different situations (increasing this number means that for example recognition is needed for firing)
- There are no mistakes. Mistakes could lead to using the wrong ammunition on the wrong target.
- Shooter and observer are at the same position

5. REQUIREMENTS FOR THE DETECTION MODULE

We are always standing open for implementing a better detection module. There are a few basic requirements the module must meet:

- Generic, a sensor has to be specified by a few characteristics, not by a model
- Simple, the level of detail must be in line with the level of detail in other modules
- Fast, the advances in computer-power will be used for simulating more complex situations as well as for a more detailed implementation
- The module must be able to cope with dynamic situations. Units move around, fire, etc
- The detection probability may not depend on the size of the timestep
- The detection module must be in line with the other modules